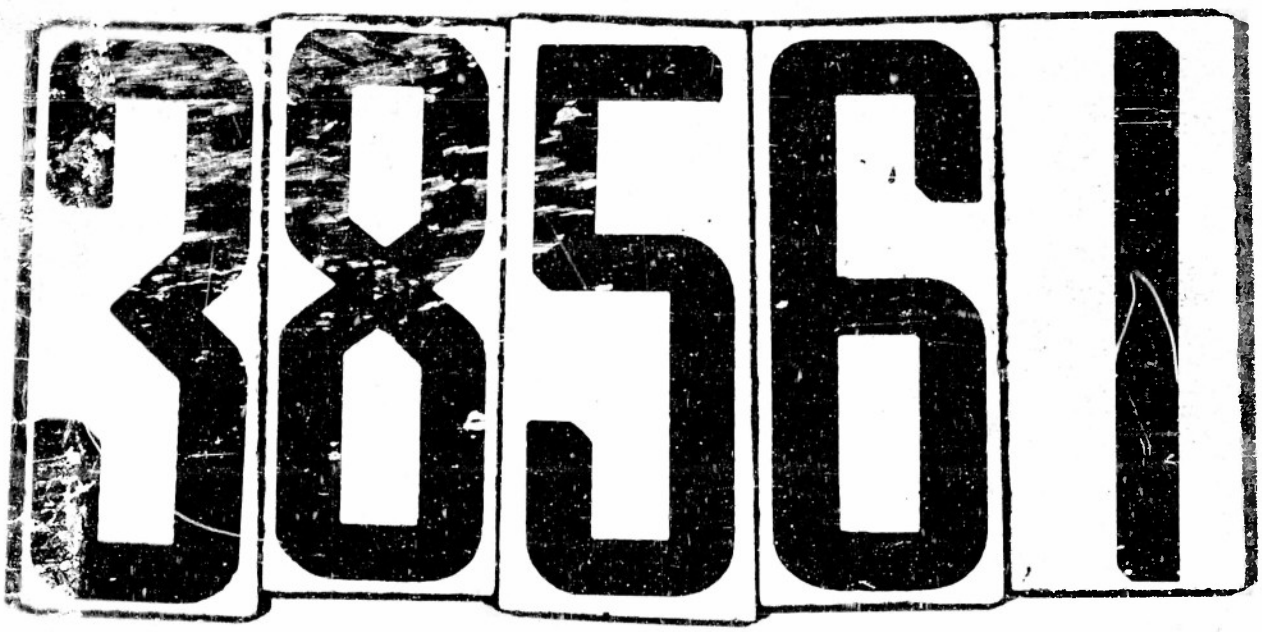
AD



UNCLASSIFIED

ARMY AIR FORCES
SCHOOL OF AVIATION MEDICINE
RANDOLPH FIELD, TEXAS

Project Report

265 30 May 1944

Legibility of aircraft instrument dials: The relative legibility of tachometer dials.

To obtain objective data that will provide specifications for optimum legibility of aircraft tachometer dials.

ons and Recommendations:

ous modifications of the Type E-10 tachometer dial have been com- the accuracy with which they can be read during brief exposures. consistent in demonstrating that the dial without subdivisions o fewer errors than dials with one or four subdivision lines. o indicate that the small numbers of the Type E-10 tachometer dial ve the accuracy with which this dial can be read. Where differences dial with the small numbers tends to be inderior to the more

recommendations of a standardized tachometer dial will be drawn pletion of measurements with certain new experimental dials.

c. It is recommended that the material of this investigation be brought to the attention of individuals responsible for establishing specifications of aircraft instrument dials.

Report by:

/s/ ROGER B. LOUCKS, Ph. D.

Approved:

/s/ ARTHUR W. MELTON, Lt. Col., AC.

Approved:

/s/ PAUL A. CAMPBELL, Lt. Col., MC.,
Director of Research.

Approved:

/s/ EUGEN G. REINARTZ, Brig. Gen., USA.,
Commandant.

ARMY AIR FORCES
SCHOOL OF AVIATION MEDICINE
RANDOLPH FIELD, TEXAS

Project Report

Project No. 265 30 May 1944

Report No. 1

1. Title: Legibility of aircraft instrument dials: The relative legibility of tachometer dials.

2. Object: To obtain objective data that will provide specifications for optimum legibility of aircraft tachometer dials.

3. Conclusions and Recommendations:

a. Various modifications of the Type E-10 tachometer dial have been compared as to the accuracy with which they can be read during brief exposures. The data are consistent in demonstrating that the dial without subdivisions gives rise to fewer errors than dials with one or four subdivision lines. The data also indicate that the small numbers of the Type E-10 tachometer dial do not improve the accuracy with which this dial can be read. Where differences do arise, the dial with the small numbers tends to be inferior to the more simple dial.

b. Final recommendations of a standardized tachometer dial will be drawn up upon completion of measurements with certain new experimental dials.

c. It is recommended that the material of this investigation be brought to the attention of individuals responsible for establishing specifications of aircraft instrument dials.

Report by:

/s/ ROGER B. LOUCKS, Ph. D.

Approved:

/s/ ARTHUR W. MELTON, Lt. Col., AC.

Approved:

/s/ PAUL A. CAMPBELL, Lt. Col., MC.,
Director of Research.

Approved:

/s/ EUGEN G. REINARTZ, Brig. Gen., USA.,
Commandant.

Discussion:

This is the initial report in a series of studies designed to establish the specifications for optimum legibility in various types of aircraft dials. The criteria of legibility used in this project are based upon the accuracy with which a series of pointer settings can be read during brief exposures of the dial. If, for example, subjects make fewer mistakes in reading one of a pair of similar aircraft instruments during brief exposures, that dial is considered to be the most legible.

It is recognized that the dial which gives the fewest errors for brief exposure readings is not necessarily the one which will make possible the most precise readings were the subject to have unlimited time. There are very few aircraft instruments, however, which must be read with great precision. It appears from interviews with pilots that those characteristics of a dial which facilitate speed and accuracy in reading are more important than those which make possible extreme precision. In fact, there seems to be general agreement that an experienced pilot reads many of his instruments by the directional position of the needle rather than by verbalizing a numerical value. This does not minimize the importance of providing dials of maximum legibility for the less experienced pilot and, particularly, for students in transition training.

Considering the fact that a depot must keep on hand more than a thousand different dials for the panel instruments of aircraft, it is evident that standardization would inevitably lead to a significant increase in efficiency and saving of manhours in the related maintenance departments. If an effort is made to bring about a policy of standardization, it would appear self-evident that the first consideration should be that of maximum legibility. In order to determine what dials are most legible, it would seem that the soundest basis of evaluation is to establish comparative norms based on actual performance in reading these dials under controlled conditions.

The order in which various types of dials are being studied in this project has been determined, in part, by the availability of certain dials. Of those dials which it was feasible to extract from Air Corps Supply, it appears that the tachometer dials, the manifold pressure dials, and certain compass dials of the remote indicator type are the most promising items for immediate study. This viewpoint arises out of the following considerations: (a) Pilots are generally agreed that these are very important instruments and refer to them frequently. (b) Due to the appreciable number of similar forms for scales of comparable range, it is possible to make comparisons which in many cases constitute a variation in but one major factor of dissimilarity. (c) As a result of the large number of divisions in these scales it is possible to conduct a strictly quantitative comparison of the relative legibility of two comparable dials. Any general characteristic fostering legibility which can be identified in these quantitative comparisons may well be applicable, in some degree, to instrument dials with divisions that are more gross, and would serve as the basis for the design of improved forms of experimental dials. The material of this report is restricted to evaluations of certain tachometer dials.

Experienced pilots inevitably become very familiar with particular dials. This would tend to affect their performance in reading dials which are new to them. In consequence, it seemed likely that naive subjects would provide more valid data, and the present study was carried out on cadets with, for the most part, not more than ten (10) hours of pilot training.

The exposure apparatus consists of a masonite panel sixteen inches (16") in width by twenty inches (20") in height which contains a row of four (4) autosyn indicators covered by individual shutters (See Fig. 1). The center-line of the four (4) indicators is fourteen inches (14") from the base of the panel, and the dials are spaced three and three-eighths inches (3-3/8") center to center. The instrument panel was supported on a desk directly in front of the subject who was seated during the test. The top of the desk was approximately thirty-two inches (32") above the floor, and the front edge of the panel was twelve inches (12") from the subject's edge of the desk.

A control box containing a battery of stepping switches made it possible to present, automatically, a series of one hundred and sixty (160) dial settings. The four (4) instruments were exposed in an irregular sequence so that the subject could not anticipate with any degree of accuracy which dial was to be read on a particular trial. The control mechanism shifted the hand or pointer of an instrument just before the shutter exposed the dial. The series of dial settings were arranged in a counterbalanced or "B" "B" "A" order so that the factor of learning would tend to be equated for the various dials.

Before a cadet was tested on a particular group of four (4) instruments he was allowed to study the dials for several minutes while being coached on the manner in which the dial settings were to be read. The first twelve (12) settings in the series of one hundred and sixty (160) trials constituted a preliminary practice series. For this preliminary period the time interval switch was set so that each exposure was four (4) seconds in length. During this practice series the subjects were corrected for any error in naming the scale units. The next sixty-eight (68) trials constituted the first portion of the test proper. These trials were given with an exposure interval of 1.5 seconds. The last portion of the test, trials eighty-one (81) through one hundred and sixty (160), were given with an exposure of .75 seconds. Successive trials were administered at a rate of ten (10) per minute, or one (1) exposure every six (6) seconds. This rate remained constant throughout all portions of the experiment regardless of the length of the actual exposure itself. The subject read the dial setting into a microphone and the operator outside the experimental room recorded the reading. No subject was used for more than one (1) comparison or was given more than one hundred ans sixty (160) trials.

In measuring the legibility of various dials, the two (2) instrument faces to be compared were always placed in the central positions. Instrument faces which were dissimilar from the dials being compared were placed in the outside positions in order to force the subject to identify the unit of the scale he was reading as well as the numerical value of the setting.

After many weeks of preliminary investigation and the running of experimental controls, the following points emerged as precautions that should be

observed in order that differences could be justifiably ascribed to certain characteristics of the dials, per se, rather than to the dial position, the configuration of the four (4) dials, or factors in the general experimental routine.

a. The two (2) central dials being compared should have an equal number of even-division or "easy" readings. That is to say, if one of the two (2) dials is given a large number of even-division settings and the other dial settings fall largely at mid-division points, a difference may appear which is an artifact of the inequality in the two (2) series of settings.

b. If the two (2) external dials are markedly dissimilar, one (1) of the two (2) central dials may have a certain degree of advantage over the other. This does not seem to be entirely a positional relationship nor is it a clear cut effect of series position. Both factors appear to create differences in the accuracy of reading the two (2) central dials which may mask true but slight differences in the legibility of the pair of instruments being evaluated.

c. Reflections from the glass covers of the insturments should be eliminated if the true differences in difficulty of the dials themselves is to be measured. In certain comparisons it has been found advisable to take readings of the dial settings when the glass covers have been removed from the instruments in order to insure that reflections were completely eliminated.

d. Calibration readings should be taken by trained observers at each test session to establish the true values of the dial settings.

Comparison Number 1.

Tachometer with four (4) mid-division lines vs. tachometer with no mid-division line.

Figure 2 shows full scale photographs of the two (2) tachometers which were used in this comparison. A major difference between the two (2) scales is that Dial No. 1 (no type designation) has four (4) short mid-division lines indicating the twenty (20) R.P.M. points on the scale, whereas Dial No. 2 (type E-10 modified) which originally had single mid-division lines for the fifty (50) R.P.M. points has had these marks obscured with flat black paint. The accompanying photographs were taken under direct and intense lighting of the dial. When these dials were mounted on the autosyns in the exposure apparatus, the only lighting was from a ceiling fixture directly above the instrument panel. Under actual test conditions, therefore, the flat black paint used to obscure the mid-division marks of Dial No. 2 was barely perceptible. Subjects were required to read both tachometers to the nearest twenty (20) R.P.M. Only the right-engine pointer moved, the left-engine pointer was fixed at the base of the scale.

Twenty-eight (28) subjects were run on this comparison resulting in a total

of of four hundred and seventy-six (476) readings* with an exposure time of 1.5 seconds and five hundred and sixty (560) judgments with an exposure time of .75 seconds. The rospective percentages of error are shown just below.

Dial	Exposure	Error	T-value showing significance of difference in two percentages.
No. 1 (4 midlines)	1.5 seconds	46%)	3.77 Clearly significant
No. 2 (No midline)	1.5 seconds	34%)	at the 1% level.
No. 1 (4 midlines)	.75 seconds	44%)	3.43 Clearly significant
No. 2 (No midline)	.75 seconds	34%)	at the 1% level.

Eighty-two (82%) percent of the subjects preferred the dial with no mid-division lines. Fourteen (14%) percent of the subjects preferred the dial with four (4) midlines. The remainder expressed no preference.

These data clearly indicate that the dial without any mid-division lines is more legible than the dial with four (4) midlines. The majority of the subjects expressed a preference for the more simple dial.

In addition to the major difference between Dial No. 1 and Dial No. 2, namely, the presence of mid-division marks, there are two minor differences which might be considered briefly in evaluating the superiority of one dial over the other. Dial No. 1 has slightly larger figures than Dial No. 2. This factor may not be of any practical significance but in any case it should operate in favor of Dial No. 1 which was demonstrated to be inferior. A further point of difference can be observed by examining the extremities of the scale for Dial No. 1. The figure thirty-five (35) is so near the thirty-fourth (34th) division mark that it may prove confusing. At the other end of the No. 1 scale, the zero mark imposes a special scale for values under four hundred (400) R.P.M. To obviate these complications the dial settings were selected so as to exclude any readings above thirty-four hundred (3400) and below four hundred (400).

---

* Note: The test series consisted of sixty-eight (68) readings at 1.5 seconds exposure (following the twelve (12) preliminary readings) and eighty (80) readings at .75 seconds exposure. The readings were divided equally among four (4) dials so that ten (10) subjects, for example, would give a total of only one hundred and seventy (170) long-exposure readings on the central dials which were being compared and two hundred (200) short-exposure readings for each of the same dials.

Comparison Number 2.

Tachometer (E-10) with one (1) midline unchanged vs. tachometer (E-10) with midline obscured. Small numbers are left intact on both dials.

Twenty (20) subjects were run on this comparison leading to a total of three hundred and forty (340) readings with an exposure time of 1.5 seconds and four hundred (400) readings with an exposure time of .75 seconds. Subjects were required to read both tachometers to the nearest twenty (20) R.P.M. Only the right-engine pointer changed position during the series. The respective percentages of error are shown below. Half of the series was run with Dial No. 2 in the left central position and half with Dial No. 2 in the right central position. This is a standard procedure used in all comparisons of this report.

Dial	Exposure	Error	T-value indicating significance.
No. 2 (E-10 no midline)	1.5 seconds	31%	.26 No significant difference.
No. 3 (E-10 unchanged)	1.5 seconds	32%	
No. 2 (E-10 no midline)	.75 seconds	34%	2.06 Significant at the 5% level.
No. 3 (E-10 unchanged)	.75 seconds	41%	

There was no clearcut preference for either dial although Dial No. 3 appeared somewhat more popular.

The experimental data just above indicate that the difference between dials was not significant for the longer exposure period. At the shorter exposure interval, the dial with the midline obscured emerges as a somewhat easier dial to read although the size of the difference is not as striking as in Comparison Number 1. It would appear, therefore, that for brief exposures the simpler dial is somewhat easier to read than the dial with the fifty (50) R.P.M. midline mark.

Comparison Number 3.

Tachometer (E-10) with midline obscured vs. tachometer (E-10) with midline and small numbers obscured.

Twenty (20) subjects were run on this comparison leading to a total of three hundred and forty (340) readings at the 1.5 second exposure and four hundred (400) readings at the .75 second exposure. The respective percentages of error are shown below:

Dial	Exposure	Error	T-value indicating significance.
No. 2 (E-10 no midline)	1.5 seconds	34%	.56 No significant difference.
No. 4 (E-10 no midline or small figures)	1.5 seconds	32%	
No. 2 (E-10 no midline)	.75 seconds	39%	1.18 No significant effect.
No. 4 (E-10 no midline or small figures)	.75 seconds	35%	

These figures indicate that the presence or absence of the small numbers in the E-10 dial, taken alone, produces no statistically significant difference in legibility as the term is used in this paper. Whatever difference there is tends to favor the more simple dial. There was no clearcut preference for either dial expressed by the cadets.

Comparison Number 4.

Tachometer (E-10) with midline obscured vs. tachometer (E-10) with midline and small numbers obscured. Subjects wearing red goggles while reading dial settings.

Twenty (20) subjects were run on this comparison leading to a total of three hundred and forty (340) readings at an exposure time of 1.5 seconds and four hundred (400) readings at an exposure time of .75 seconds. Red goggles which cut down the transmission approximately seven (7%) percent were worn by the subjects in order to determine whether the minor difference found in Comparison No. 3 would be sustained under conditions of diminished visibility.

Dial	Exposure	Error	T-value indicating significance.
No. 2 (E-10 no midline)	1.5 seconds	52%)	2.10 Significant at the 5% level.
No. 4 (E-10 no midline or small figures)	1.5 seconds	60%)	
No. 2 (E-10 no midline)	.75 seconds	60%)	.29 No significant difference.
No. 4 (E-10 no midline or small figures)	.75 seconds	61%)	

A majority of the subjects preferred the simpler of the two dials.

The figures just above indicate that while the subjects are wearing red goggles which diminish the transmission of light, at the 1.5 second exposure the simpler dial is read somewhat more accurately than the dial with the small figures. There is no significant difference between the two (2) dials at the shorter exposure period.

When the subjects were interviewed as to their preferences in these dials a considerable number of them indicated that the small numbers tended to confuse them. When questioned further, it appeared that the small figures tended to attract the attention of the subjects and in trying to decipher them they were slowed up in estimating the position of the dial hand. On the basis of these interviews the hypothesis may be advanced that when the subjects were wearing red goggles the visibility was so low that at the .75 second exposure the small numbers had no appreciable distraction effect, and for all practical purposes the two dials were the same. At the 1.5 second exposure interval, even with reduced visibility, the small numbers tended to attract the subjects' attention sufficiently to interfere with their estimating the pointer's position. In the previous comparison (No. 3) where the same dials were read without glasses the visibility was such that only at the short exposure was the distraction value of the small numbers of any appreciable significance. Whatever the validity of this hypothesis, it may be said that any difference that appears is in favor of the more simple dial. Or conversely, it can be stated more positively that in none of the comparisons for either short or long inter-

vals have the small numbers contributed significantly to either the speed or accuracy in reading the E-10 dial.

Comparison Number 5. (Control)

Tachometer (E-10) no midline or small figures vs. the same dial, i.e., tachometer (E-10) no midline or small figures.

Forty (40) subjects were run on this comparison leading to a total of six hundred and eighty (680) readings at an exposure time of 1.5 seconds and eight hundred (800) readings at an exposure time of .75 seconds. Half of the subjects were run with one of the identical dials in the left central position; the second half of the group was run with one of the identical dials in the right central position. Comparison Number 5 was instituted in order to make sure that there was not some slight difference in two (2) dials of the same style and form which might lead to a minor but consistent difference.

Dial	Exposure	Error	T-value indicating significance.
No. 4 (E-10 no midline or small figures)	1.5 seconds	23%	.87 No significant difference.
No. 4 (E-10 no midline or small figures)	1.5 seconds	25%	
No. 4 (E-10 no midline or small figures)	.75 seconds	19%	.50 No significant difference.
No. 4 (E-10 no midline or small figures)	.75 seconds	20%	

No preference was expressed for one dial or position over the other dial or position.

The various comparisons which have been considered in this paper can be summarized by stating that the fewer the subdivisions, the simpler or 'cleaner' the dial, the more legible it proves to be.

As a consequence of these findings specifications have been drawn up for four (4) experimental dials which constitute variations of the E-10 type of dial. These new forms will make it possible to establish, under systematic and controlled comparisons, the relative significance of the following factors:

a. Legibility of main division marks that are half the width of the present lines on the E-10 dial.

b. Relative legibility of division numbers that are larger than the present figures.

c. Relative legibility of a scale where numbers somewhat smaller than those of the E-10 dial are placed at all main divisions.

Arrangements have now been completed which make it possible to have these dials made up at the Kelly Field engineering shops so that they will conform

in style and workmanship to the standard E-10 dial. It is planned to test these dials under ultraviolet irradiation as well as conditions of reduced reflected light so as to determine the overall legibility of the finer main division lines and other modifications.

While these dials and alternate forms for manifold pressure indicators, remote indicating compass indicators, and climb indicators are being constructed, various styles of instrument pointers are being tested to see if the area of fluorescent paint can be reduced without decreasing the legibility of the total assembly. These pointers are being tested under conditions of ultraviolet excitation as well as reflected light.

Conclusions:

Various modifications of the Type E-10 tachometer dial have been compared as to legibility at 1.5 second and .75 second exposures.

The data are consistent in demonstrating that the dial without any subdivisions gives rise to fewer errors, when read at brief exposure intervals, than dials with one (1) or four (4) subdivision lines.

Specific investigation has demonstrated that the small numbers of the E-10 dial do not improve the legibility of these types of indicator faces. Where differences do arise the dial with the small numbers tends to be inferior to the more simple dial.

Upon the basis of the present findings four (4) new experimental dials are being constructed at Air Corps engineering shops which will be similar in workmanship to the standard E-10 tachometer dial and will make it possible to establish final specifications for optimum legibility as it is affected by width of division lines and size of numerals.

Pending the delivery of these new dials various types of indicator pointers are being tested to see if the area of luminous paint can be diminished without reducing legibility.

Final recommendations of a standardized tachometer dial will be drawn up upon the completion of measurements on these modifications of the E-10 tachometer dial. These measurements can be carried out in a short period of time as all basic controls have been completed in the present study.

The present study has included an investigation of dial pattern and the influence of relative difficulty in the specific settings of dials being tested. The investigation has shown that these factors must be carefully controlled if results are to be ascribed to differences in the specific dials being compared rather than to artifacts of the general experimental set-up and routine.

Using the general principle established in this investigation that the more simple the dial, the more legible it proves to be, modified forms of standard manifold pressure dials, remote indicator compass dials, and climb indicator dials are being constructed so that systematic comparisons can be run which will ultimately make it possible to formulate specifications for maximum legibility in these types of instruments.

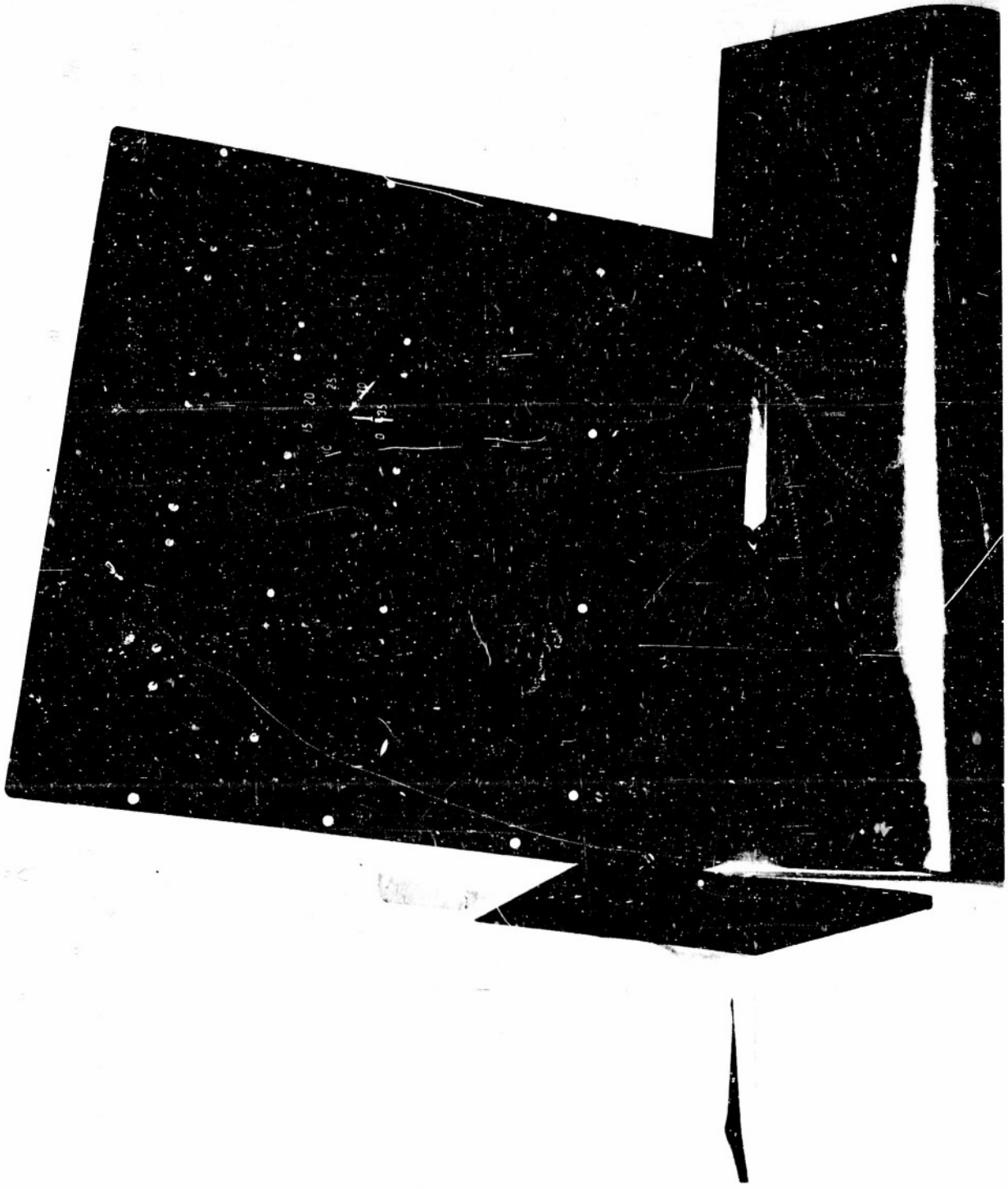
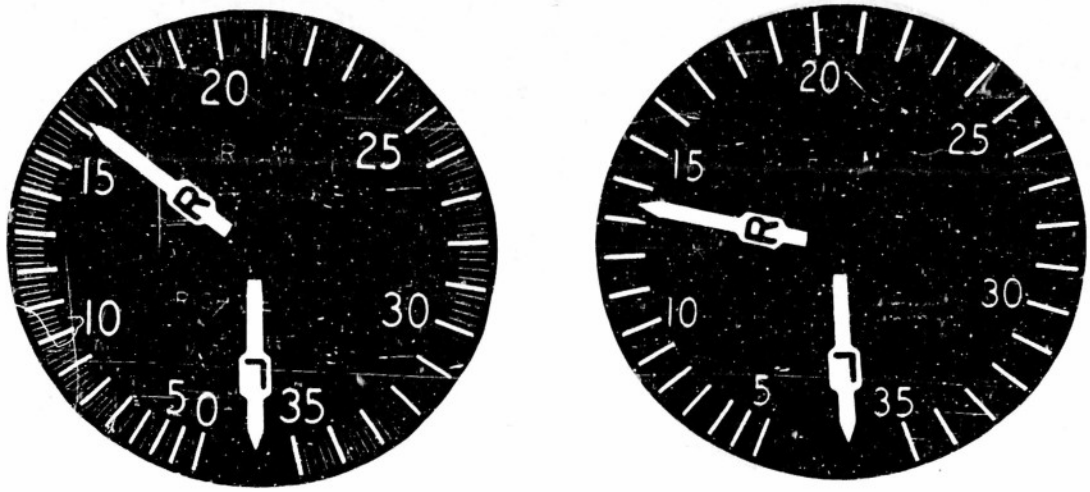


Figure 2. Comparison Number 1. Tachometer with four mid-division lines vs. tachometer (E-10) with mid-line obscured.



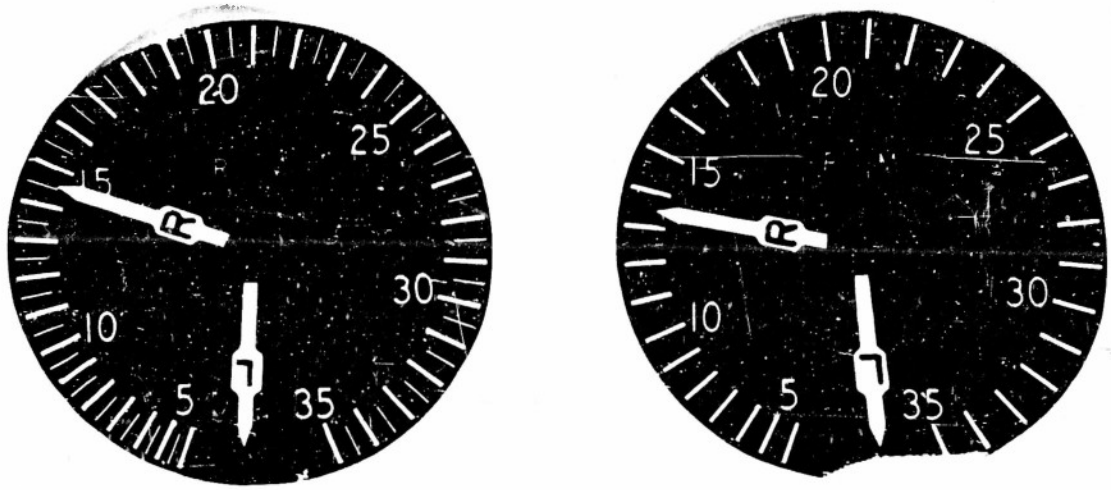
Dial No. 1
46% error at 1.5 sec. exposure
(Significant difference at 1% level)

44% error at .75 sec. exposure
(Significant difference at 1% level)

Dial No. 2
34% error at 1.5 sec. exposure

34% error at .75 sec. exposure

Figure 3. Comparison Number 2. Tachometer (E-10) with one mid-line, unchanged, vs. tachometer (E-10) with mid-line obscured.



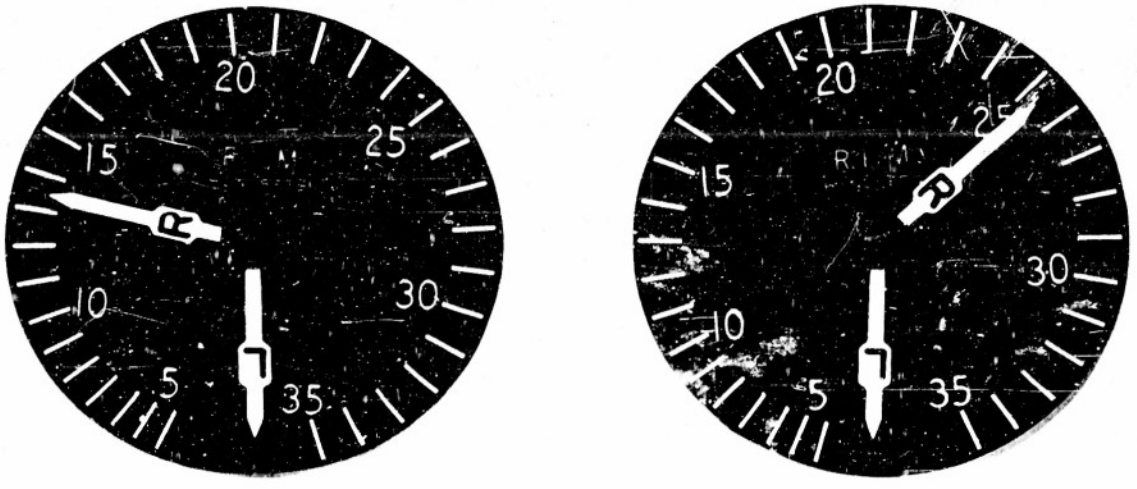
Dial No. 3
32% error at 1.5 sec. exposure
(No significant difference)

41% error at .75 sec. exposure
(Significant difference at 5% level)

Dial No. 2
31% error at 1.5 sec. exposure

34% error at .75 sec. exposure

Figure 4. Comparison Number 3. Tachometer (E-10) with mid-line obscured vs. tachometer (E-10) with mid-line and small numbers obscured.



Dial No. 2	Dial No. 4
34% error at 1.5 sec. exposure	32% error at 1.5 sec. exposure
(No significant difference)	
39% error at .75 sec. exposure	35% error at .75 sec. exposure
(No significant difference)	

Comparison Number 4. Dials as in Comparison Number 3 but subjects wearing red goggles that cut transmission of light 7%.

Dial No. 2	Dial No. 4
52% error at 1.5 sec. exposure	60% error at 1.5 sec. exposure
(Significant difference at 5% level)	
60% error at .75 sec. exposure	61% error at .75 sec. exposure
(No significant difference)	

Comparison Number 5. Tachometer (E-10) no mid-line or small figures vs. tachometer (E-10) no mid-line or small figures. (Control)

Dial No. 4	Dial No. 4
25% error at 1.5 sec. exposure	23% error at 1.5 sec. exposure
(No significant difference)	
20% error at .75 sec. exposure	19% error at .75 sec. exposure
(No significant difference)	